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SINGLE-MODE BEND EVALUATIONS. ADDENDUM, (U)

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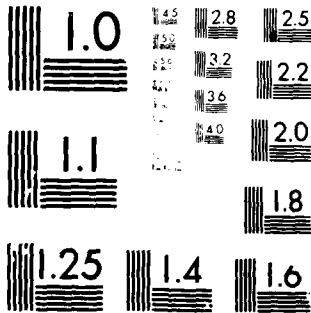
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TABLE OF CONTENTS

<u>PARAGRAPH</u>	<u>TITLE</u>	<u>PAGE</u>
1.0	INTRODUCTION	1-1
2.0	SINGLE-MODE FIBER BEND LOSS STUDY	2-1
2.1	Evaluation of the Bend Loss	2-1
2.1.1	Monitor Coupler	2-3
2.1.2	Double Wind Mandrel	2-3
2.2	Method of Evaluation	2-3
3.0	RESULTS OF THE EVALUATIONS	3-1

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LIST OF ILLUSTRATIONS

<u>FIGURE</u>	<u>TITLE</u>	<u>PAGE</u>
2-1	Bend Loss Measurement Station	2-2
2-2	Monitoring Coupler	2-4
2-3	Monitoring Coupler Housing	2-5
2-4	Single-Mode Fiber Bending Loss Test Apparatus	2-6
3-1	EMT-21182a - 1-cm Mandrel - 0.63282 μm	3-4
3-2	EMT-21182a - 2-cm Mandrel - 0.63282 μm	3-5
3-3	EMT-21182a - 1-cm Mandrel - 0.84 μm	3-6
3-4	EMT-21182a - 2-cm Mandrel - 0.84 μm	3-7
3-5	EM-20413 - 1-cm Mandrel - 0.63282 μm	3-8
3-6	EM-20413 - 2-cm Mandrel - 0.63282 μm	3-9
3-7	EM-20413 - 1-cm Mandrel - 0.84 μm	3-10
3-8	EM-20413 - 2-cm Mandrel - 0.84 μm	3-11
3-9	EM-20588 - 1-cm Mandrel - 0.63282 μm	3-12
3-10	EM-20588 - 2-cm Mandrel - 0.63282 μm	3-13
3-11	EM-20588 - 1-cm Mandrel - 0.84 μm	3-14
3-12	EM-20588 - 2-cm Mandrel - 0.84 μm	3-15
3-13	EM-20495 - 1-cm Mandrel - 0.63282 μm	3-16
3-14	EM-20495 - 2-cm Mandrel - 0.63282 μm	3-17
3-15	EM-20495 - 1-cm Mandrel - 0.84 μm	3-18
3-16	EM-20495 - 2-cm Mandrel - 0.84 μm	3-19

LIST OF TABLES

<u>TABLE</u>	<u>TITLE</u>	<u>PAGE</u>
3-1	Experimental Results	3-5

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1.0 INTRODUCTION

This test is designed to find the bend-induced losses of four fibers. Three of these fibers are of the high numerical aperture (NA) design, and one fiber is of the low NA design.

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2.0 SINGLE-MODE FIBER BEND LOSS STUDY

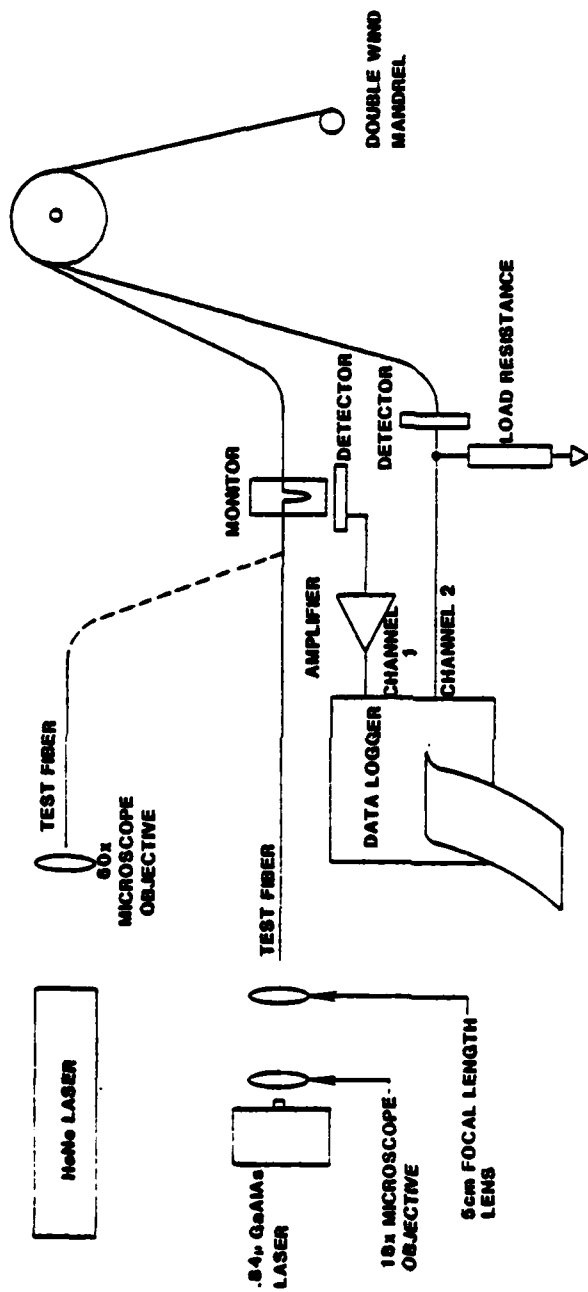
This test evaluates the bend-induced losses within a single-mode fiber at 0.63282 μm from a helium neon laser and at 0.84 μm from a gallium aluminum arsenide laser. Three of the fibers used in the tests were made in the earlier section of this contract. A low NA fiber for use in this experiment was supplied by ITT EOPD.

2.1 Evaluation of the Bend Loss

The bend loss was evaluated using the equipment in Figure 2-1. This design makes use of a monitor coupler to improve measurement accuracy. The monitor coupler provides a signal which is directly proportional to the power in the fiber and can, therefore, be used as a reference. A transimpedance amplifier provides amplification of the signal for recording.

The throughput power is detected by means of a photovoltaic detector with a fixed load. Both the throughput signal and the amplified monitor signal are recorded by means of a printing data logger.

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Figure 2-1. Bend Loss Measurement Station.

2.1.1 Monitor Coupler

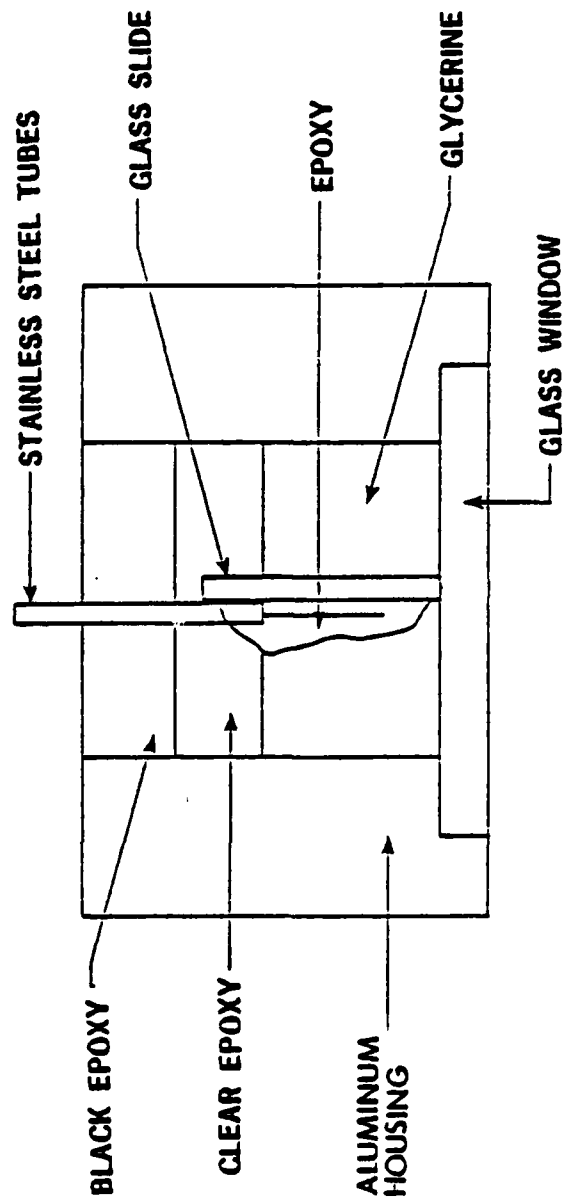
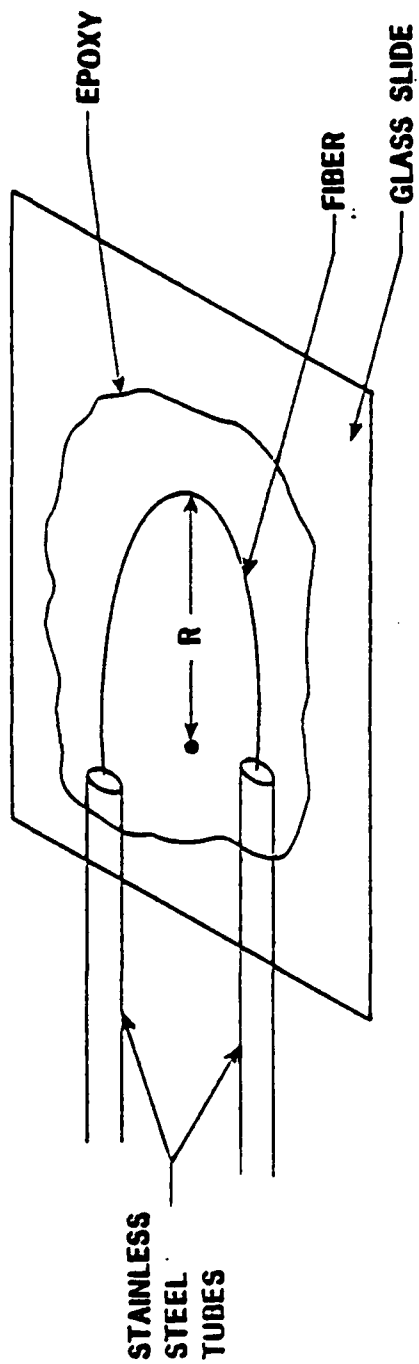
The monitor coupler used in this series of tests is shown in Figure 2-2 and the detector housing with completed coupler installed is shown in Figure 2-3. The detector collects the radiation emitted from the fiber providing an output signal to the amplifier. The monitor power was required to linearly track the output power within 5% as the output power is varied from 100% to 25%.

2.1.2 Double Wind Mandrel

The double wind mandrel is shown in Figure 2-4. It is designed so that when the fiber is wound onto the mandrel, it winds in both directions. Two mandrel sizes, 1 cm and 2 cm, were used in this test. It is worth noting that mandrels of this design provide six transition regions. Four transition regions occur when the fiber winds onto or off the mandrel and two when the fiber is wound around the 5-cm diameter disk shown at the center of the mandrel.

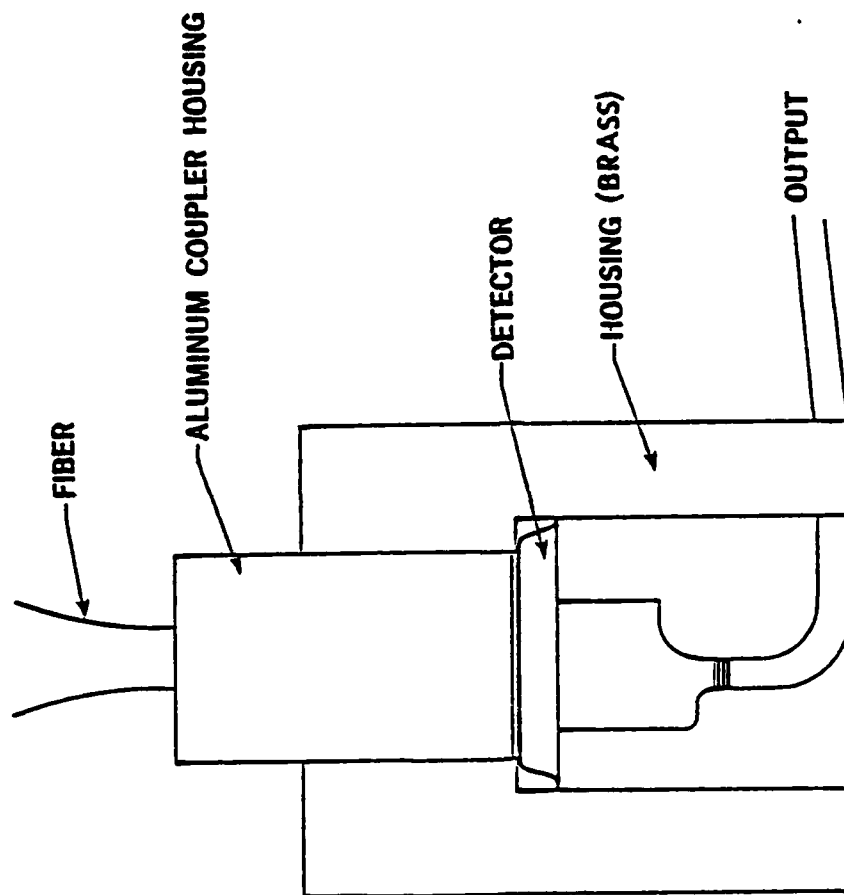
2.2 Method of Evaluation

In these tests the fiber is wound onto the mandrel with 5, 30, 100, 200, and 300 turns. An unwound measurement



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Figure 2-2. Monitoring Coupler.



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Figure 2-3. Monitoring Coupler Housing.

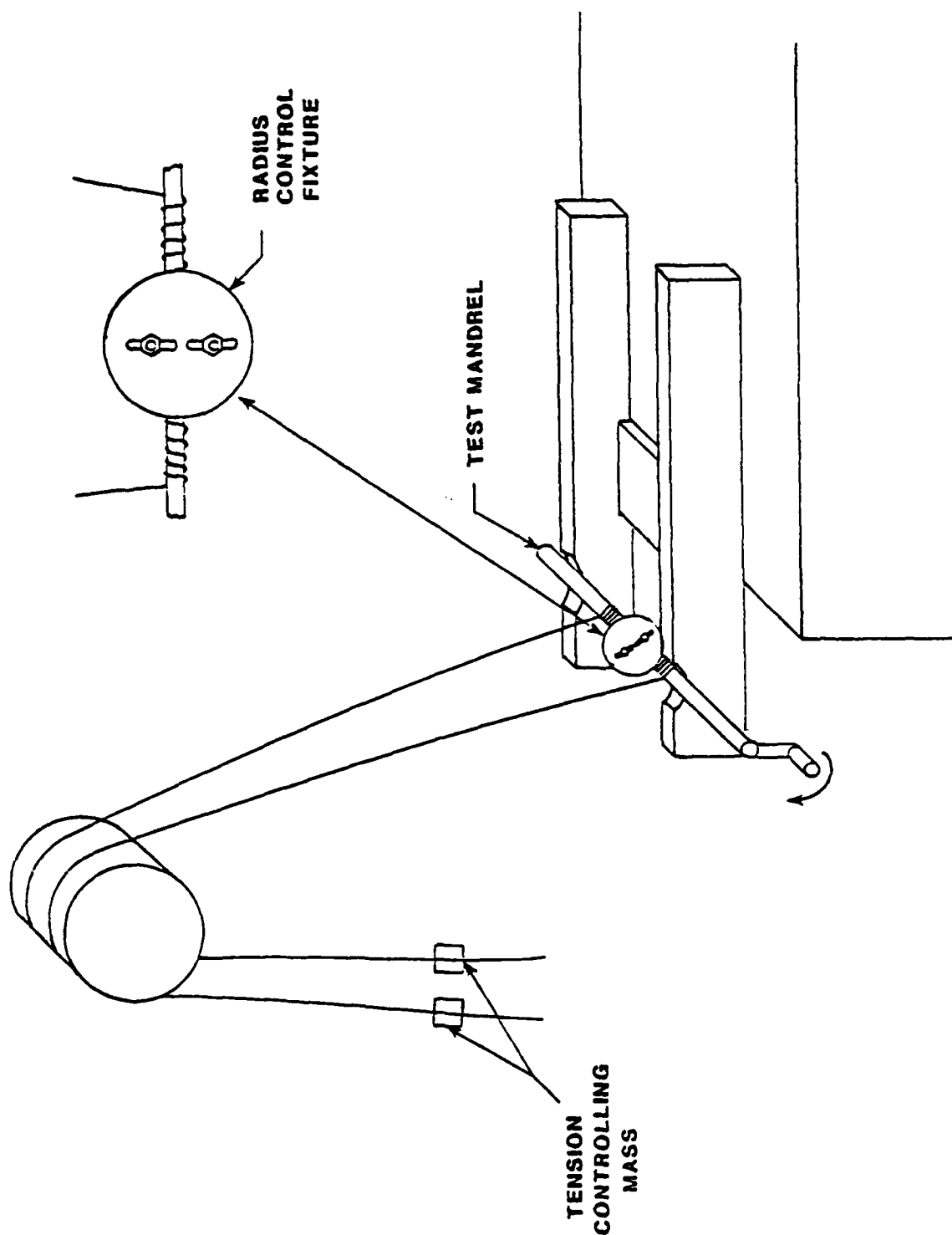


Figure 2-4. Single-Mode Fiber Bending Loss Test Apparatus. 302 12230

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is also made. The tap power and the output power are measured at each stage using the data logger. A minimum of 10 samples was taken. These measurements were performed on both mandrels at both wavelengths on all four fibers.

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3.0 RESULTS OF THE EVALUATIONS

In the experiment the loss is evaluated according to the ratio of the throughput signal to the tap signal. This ratio is

$$r = \frac{V_{\text{through}}}{V_{\text{tap}}} = \frac{P_{\text{through}} R_1 R_L}{P_{\text{tap}} R_2 R_f} \quad (3-1)$$

where P_{through} and P_{tap} are the throughput and monitor coupler powers, R_1 and R_2 are the responsivities of the throughput power and monitor power detectors respectively, R_L is the load resistor on the throughput power detector and R_f is the feedback resistor on the transimpedance amplifier in the monitor circuit.

Thus the induced loss is

$$Y = 10 \log \frac{r_t}{r_o} = -10 \log \left(\frac{P_{\text{th}}(t)}{P_{\text{th}}(o)} \cdot \frac{P_{\text{tap}}(o)}{P_{\text{tap}}(t)} \right) \quad (3-2)$$

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where the subscript t indicates the number of turns and the subscript o is zero turns. This technique allows the loss compensated for the effects of injection conditions to be expressed.

The two components of the loss can now be expressed as

$$\text{Initial loss} = -10 \log_{10} \left(\frac{r_5}{r_o} \right) \text{ in dB} \quad (3-3)$$

$$\text{Final loss} = -10 \log_{10} \left(\frac{r_{300}}{r_{30}} \right) \times \frac{1}{270} \text{ in dB/turn} \quad (3-4)$$

The negative sign is included so that positive loss is attenuation and negative loss is gain.

In practice the standard experimental error due to amplifier drift and various noise sources is approximately 3%. Thus, it is possible to obtain negative loss answers on very resistant fibers. The results of this experiment are summarized in Table 3-1 and plotted as

$$\text{Percent variation} = 100 \left(\frac{r_t}{r_o} \right) \quad (3-5)$$

on semilog paper in Figures 3-1 through 3-16 inclusive.

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Table 3-1. Experimental Results.

Fiber Number	NA	Mandrel Size	0.63282 μm		0.63282 μm		0.84 μm	
			Initial	Loss	Per Turn	Loss	Initial	Per Turn
EMT 21182a	0.10	1 cm	9.95 dB		0.45 dB/turn ¹		19.32 dB	0.065 dB/turn ¹
		2 cm	-0.05		0.002		13.4	0.147 ²
EM 20413	0.15	1 cm	0.35		0.023		19.1	0.034
		2 cm	-0.10		0		1.06	0.09
EM-20588	0.20	1 cm	0.047		0.0002		-0.008	0.003
		2 cm	0.06		0.0005		0.028	0.0002
EM-20495	0.20	1 cm	0.27		-0.0001		-0.02	-0.0002
		2 cm	-0.044		-0.0005		0.002	-0.00024

5-5

¹Number found using 30 turns and 5 turns

²Number found using 100 turns and 5 turns

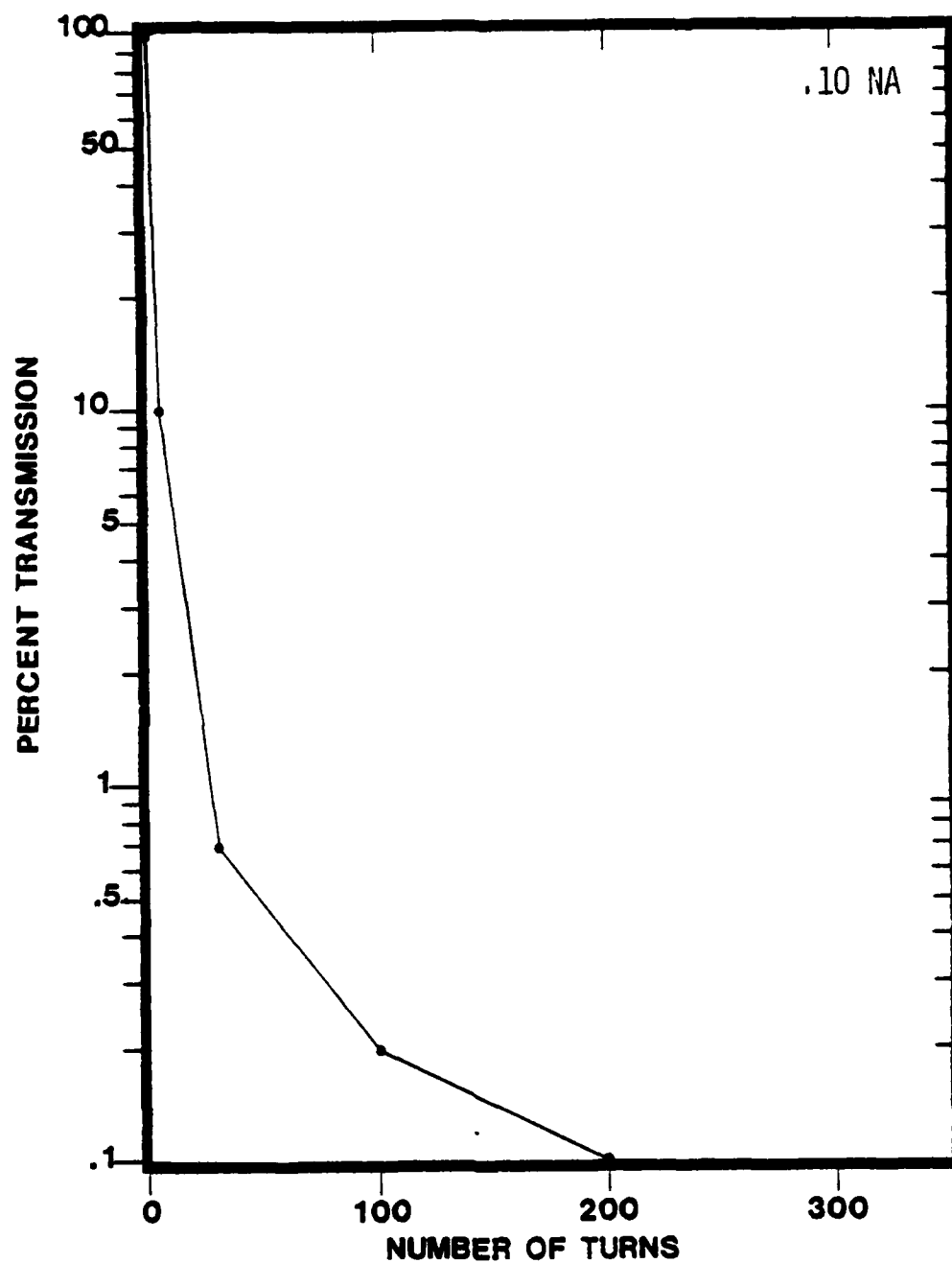


Figure 3-1. EMT-21182a - 1-cm Mandrel - $0.63282 \mu\text{m}$.

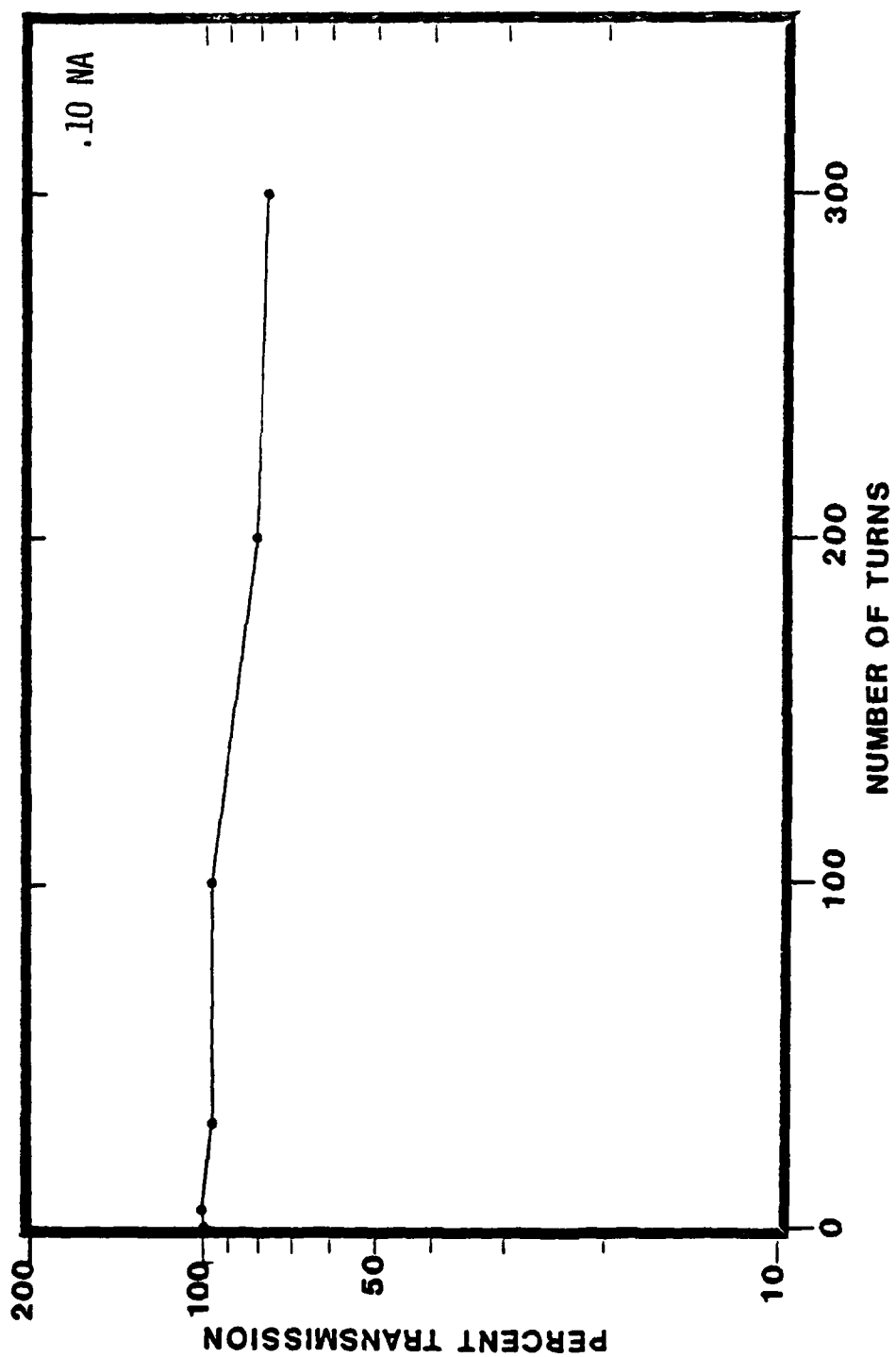


Figure 3-2. EMT-21182a - 2-cm Mandrel - 0.63282 μm .

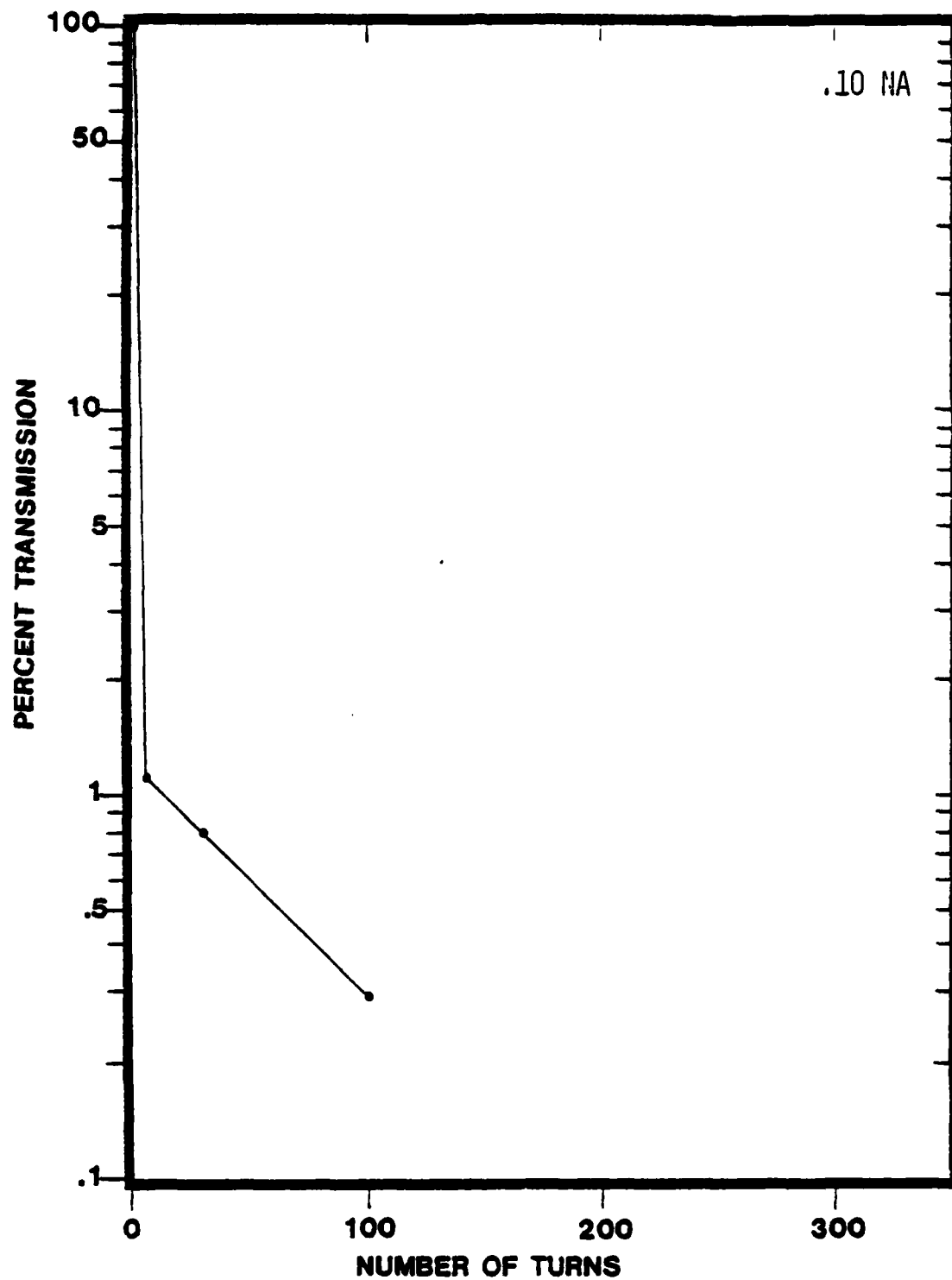


Figure 3-3. EMT-21182a - 1-cm Mandrel - 0.84 μm .

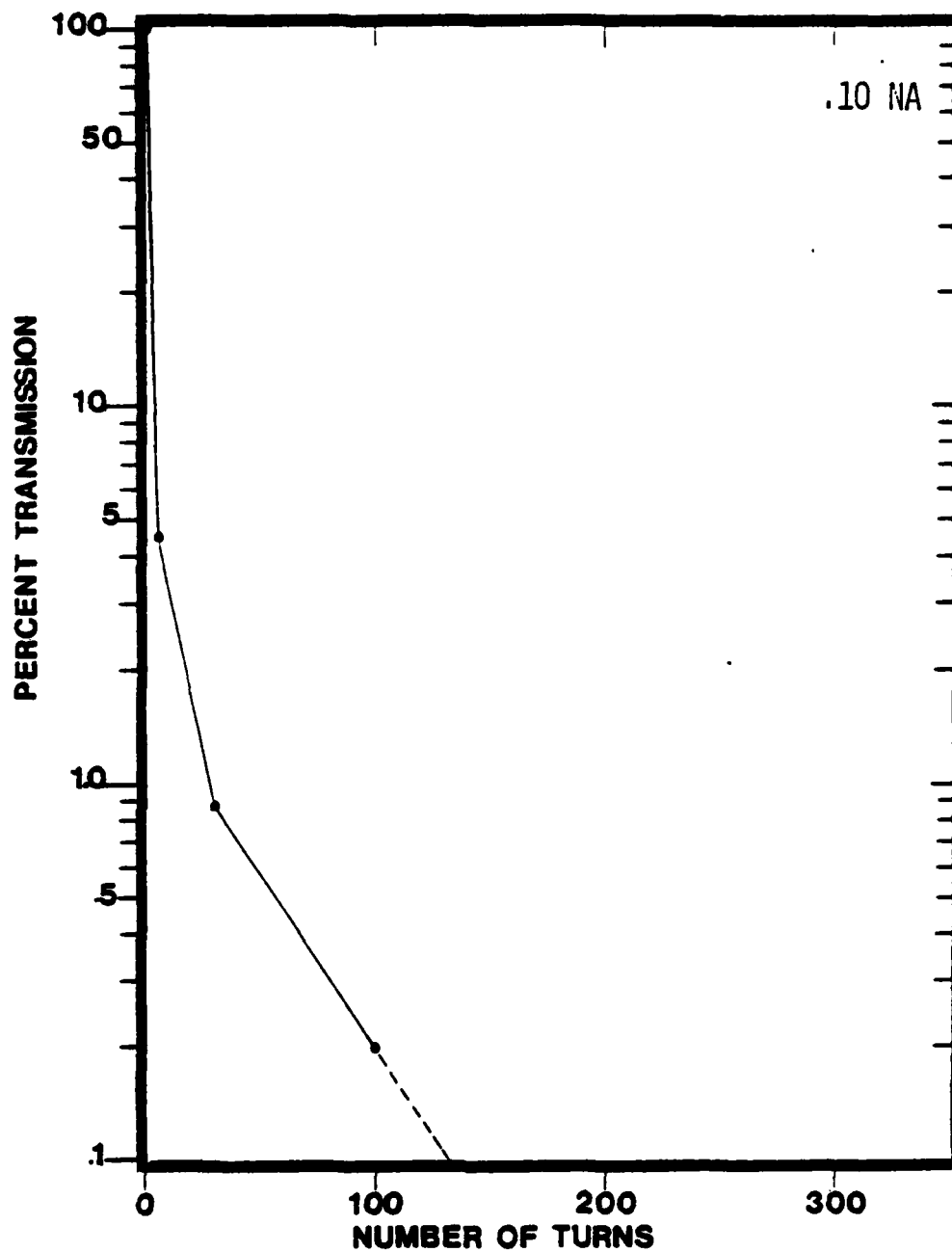


Figure 3-4. EMT-21182a - 2-cm Mandrel - 0.84 μm .

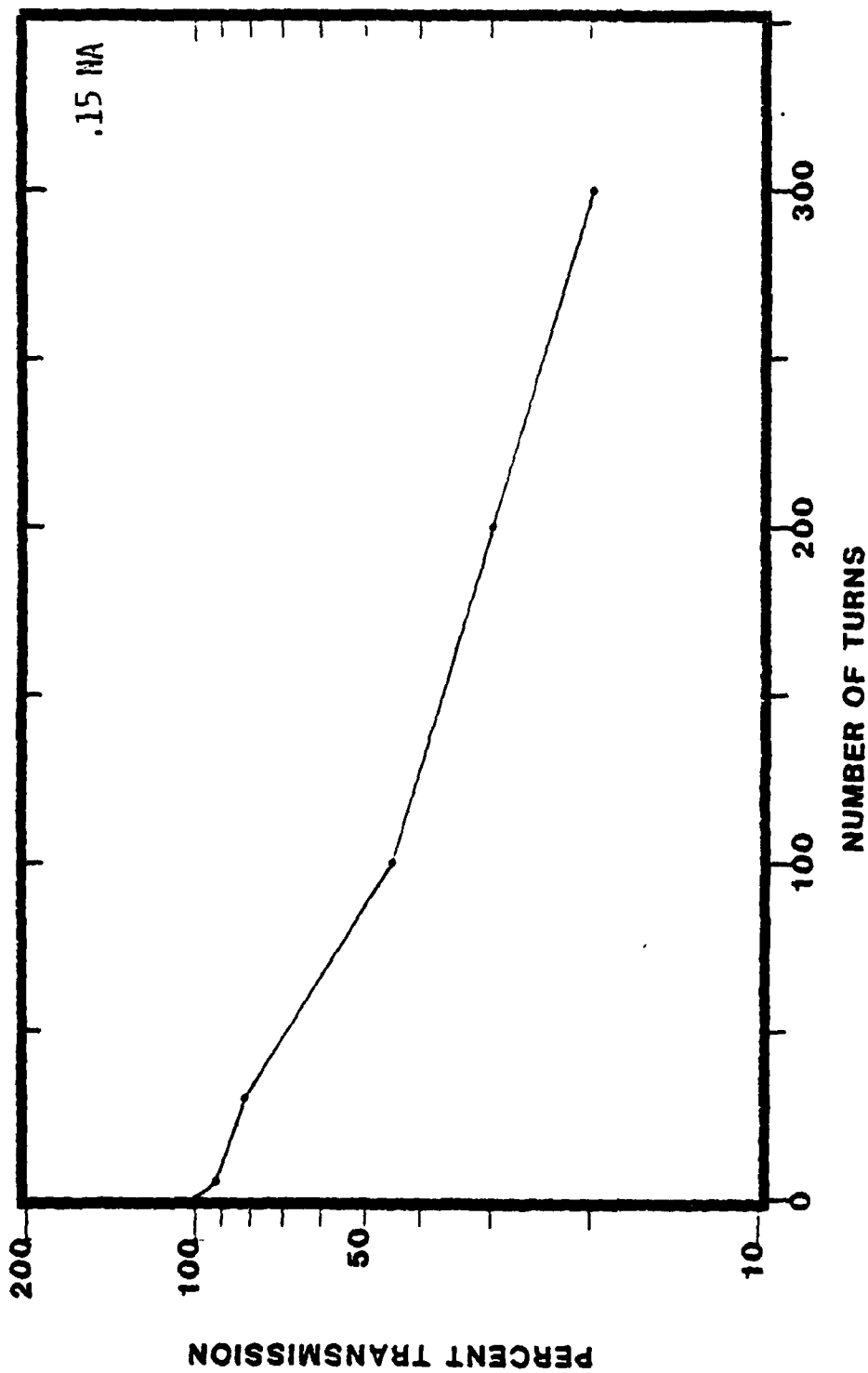


Figure 3-5. EM-20413 - 1-cm Mandrel - 0.63282 μm . 302 13222

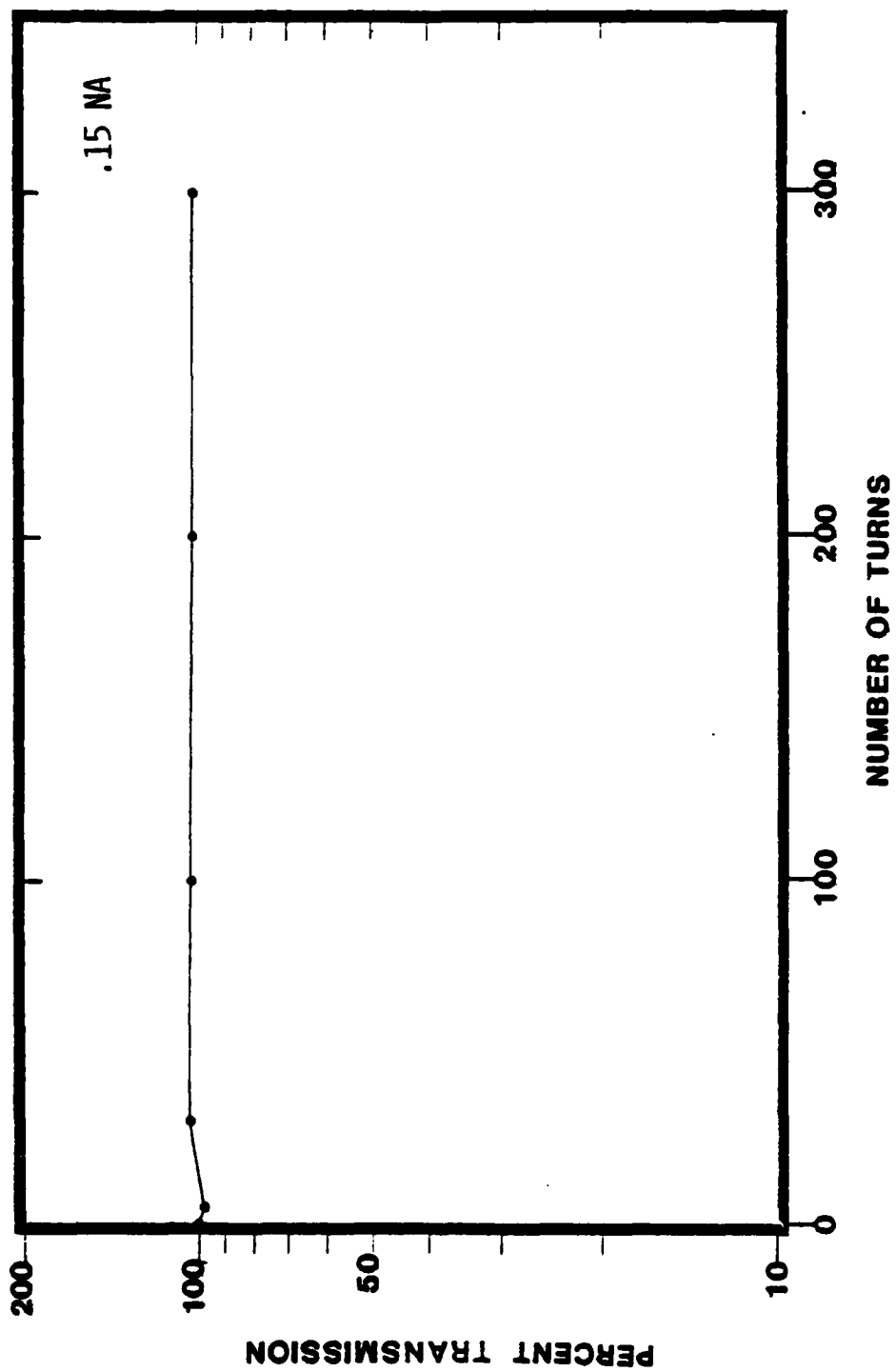


Figure 3-6. EM-20413 - 2-cm Mandrel - 0.63282 μm.

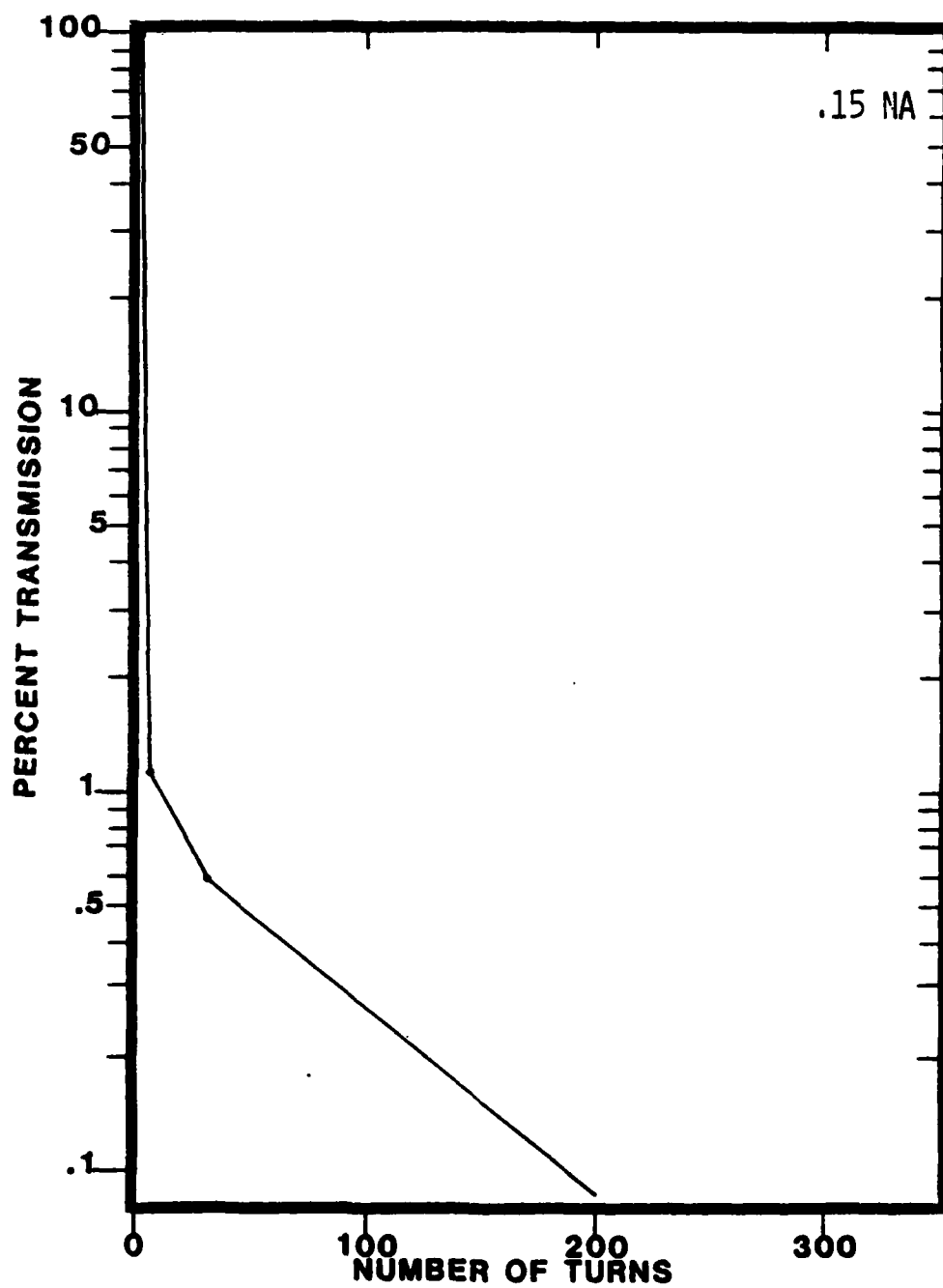


Figure 3-7. EM-20413 - 1-cm Mandrel - 0.84 μm .

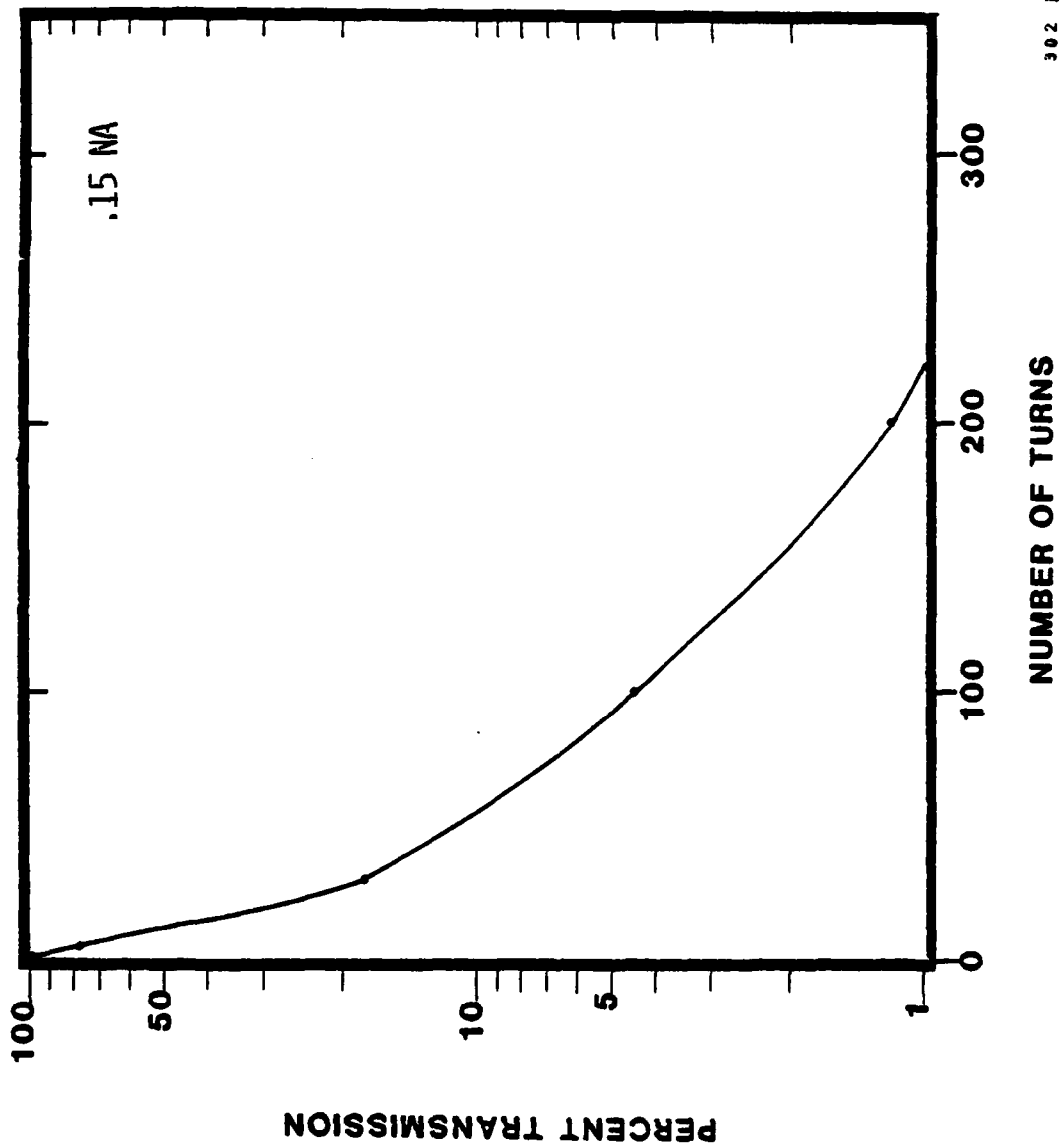


Figure 3-8. EM-20413 - 2-cm Mandrel - 0.84 μm .

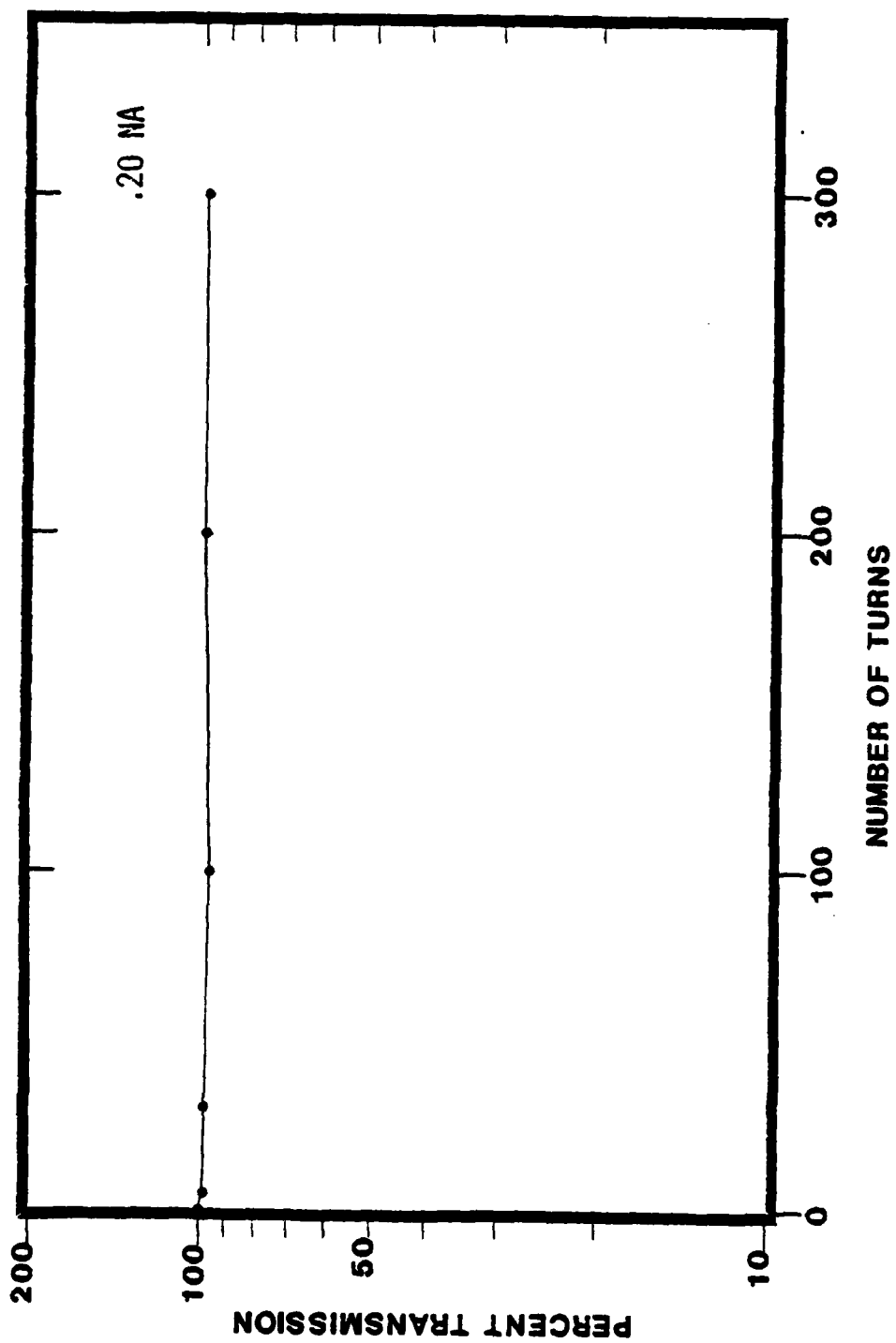


Figure 3-9. EM-20588 - 1-cm Mandrel - 0.63282 μm .

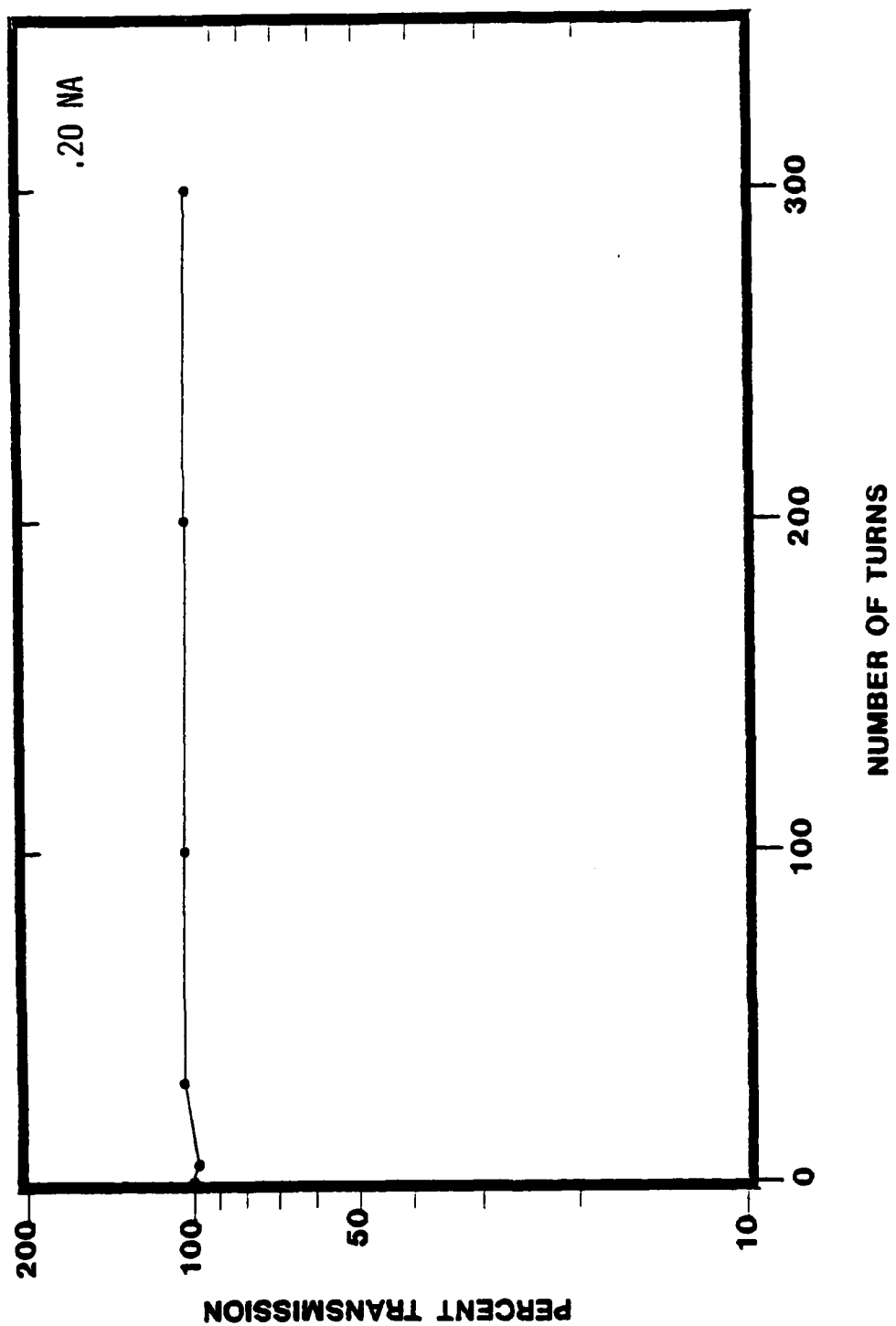
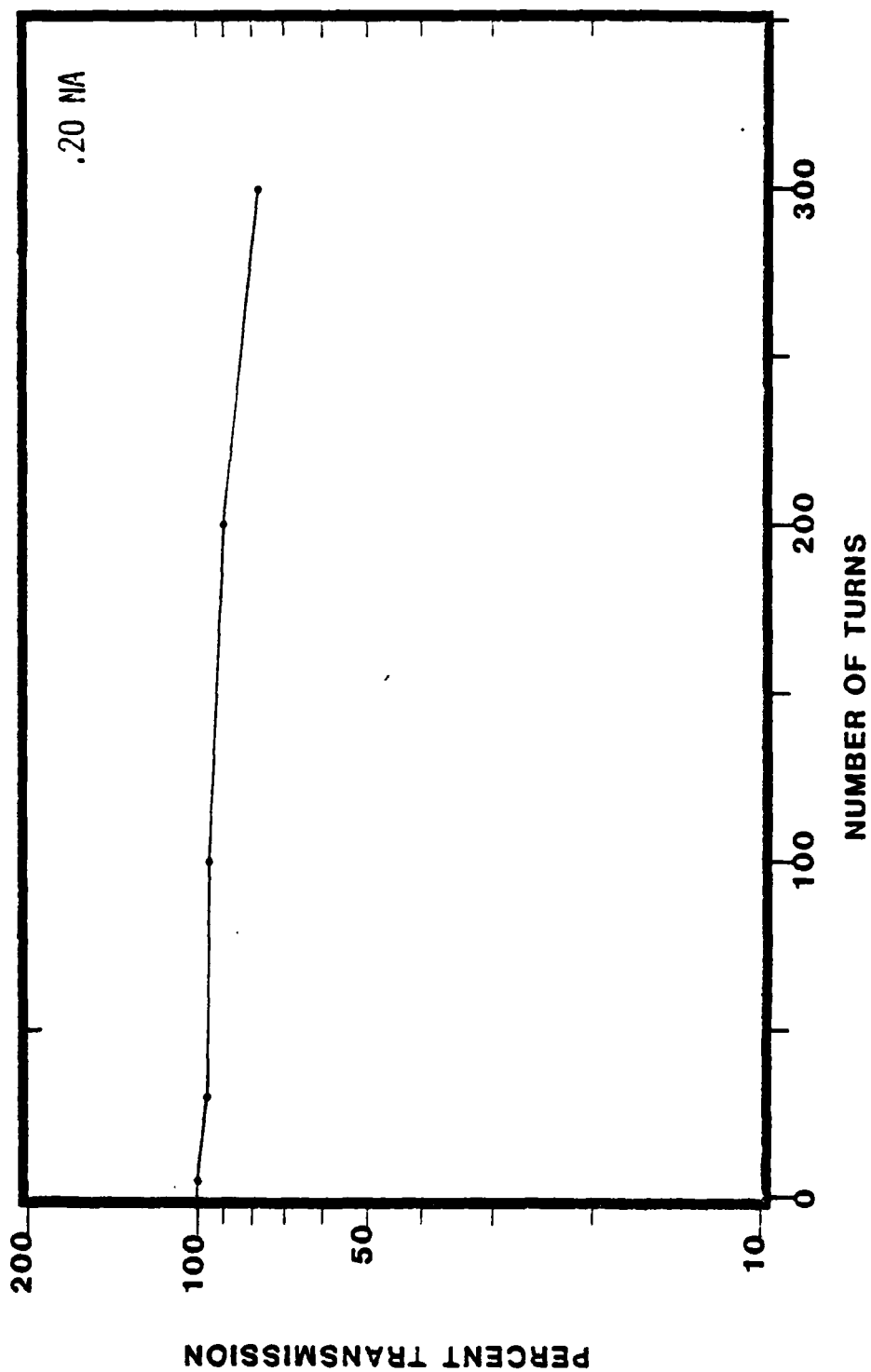
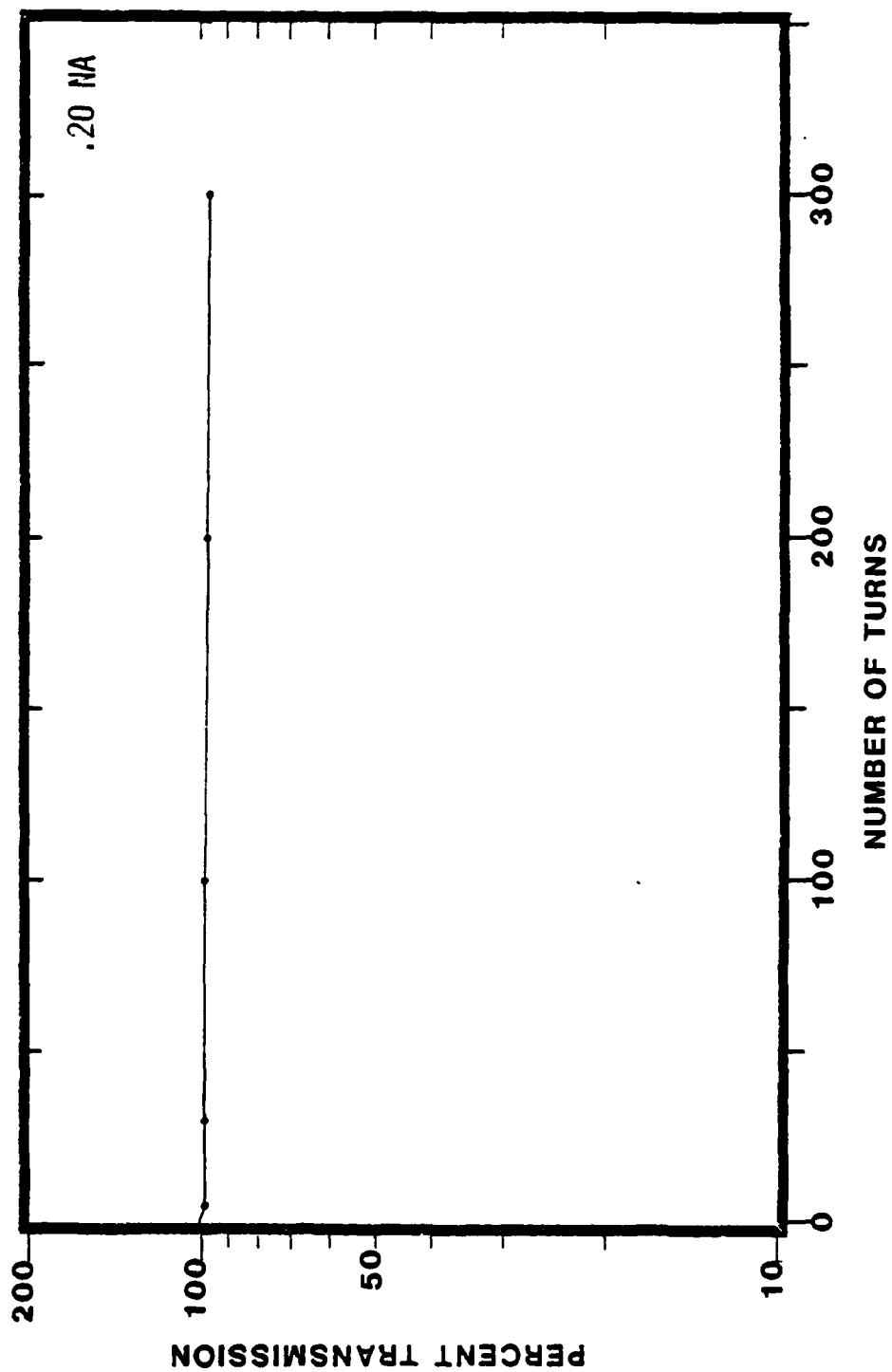


Figure 3-10. EM-20588 - 2-cm Mandrel - 0.63282 μm.



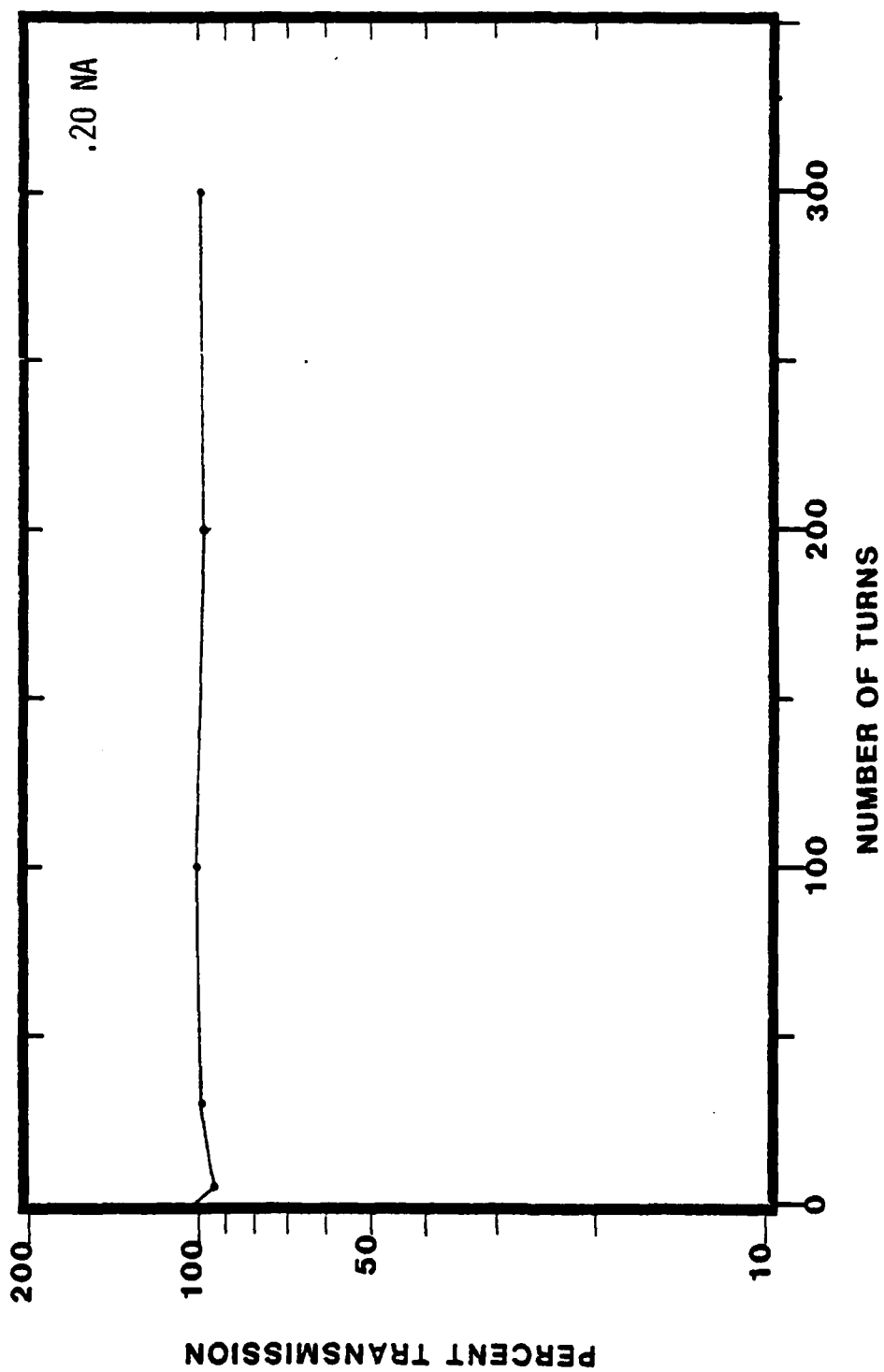
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Figure 3-11. EM-20588 - 1-cm Mandrel - 0.84 μm .



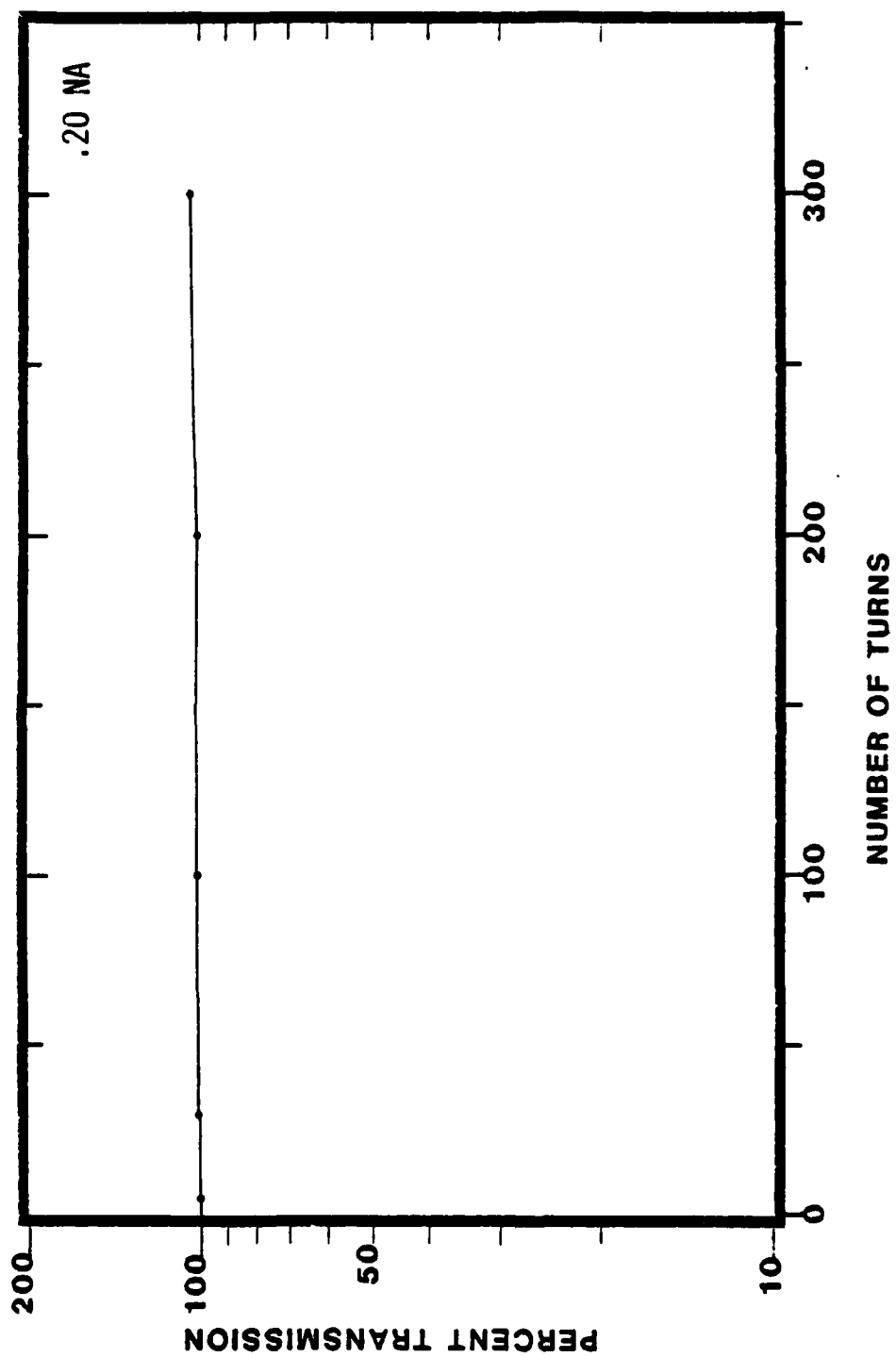
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Figure 3-12. EM-20588 - 2-cm Mandrel - 0.84 μm .



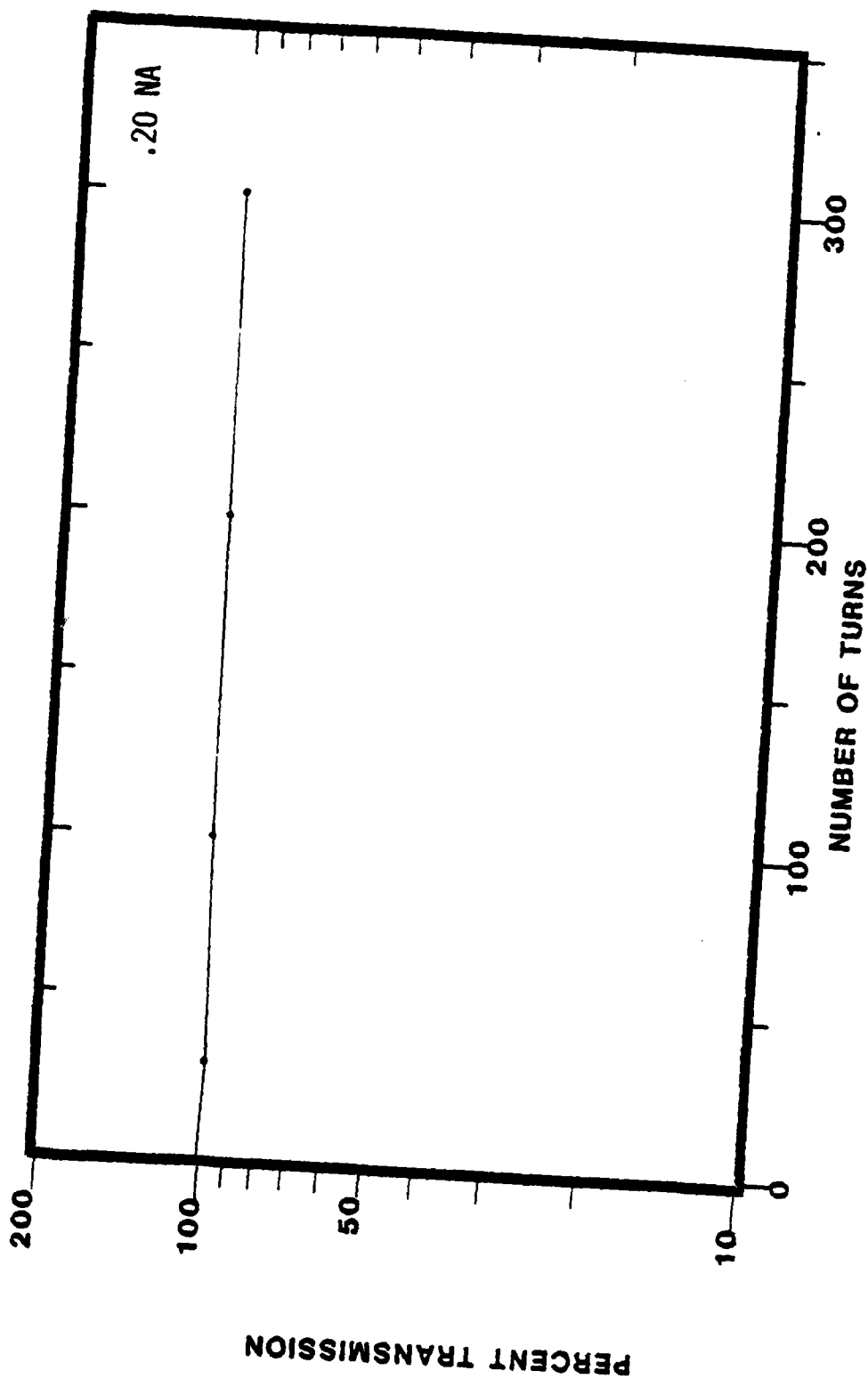
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Figure 3-13. EM-20495 - 1-cm Mandrel - 0.63282 μm .



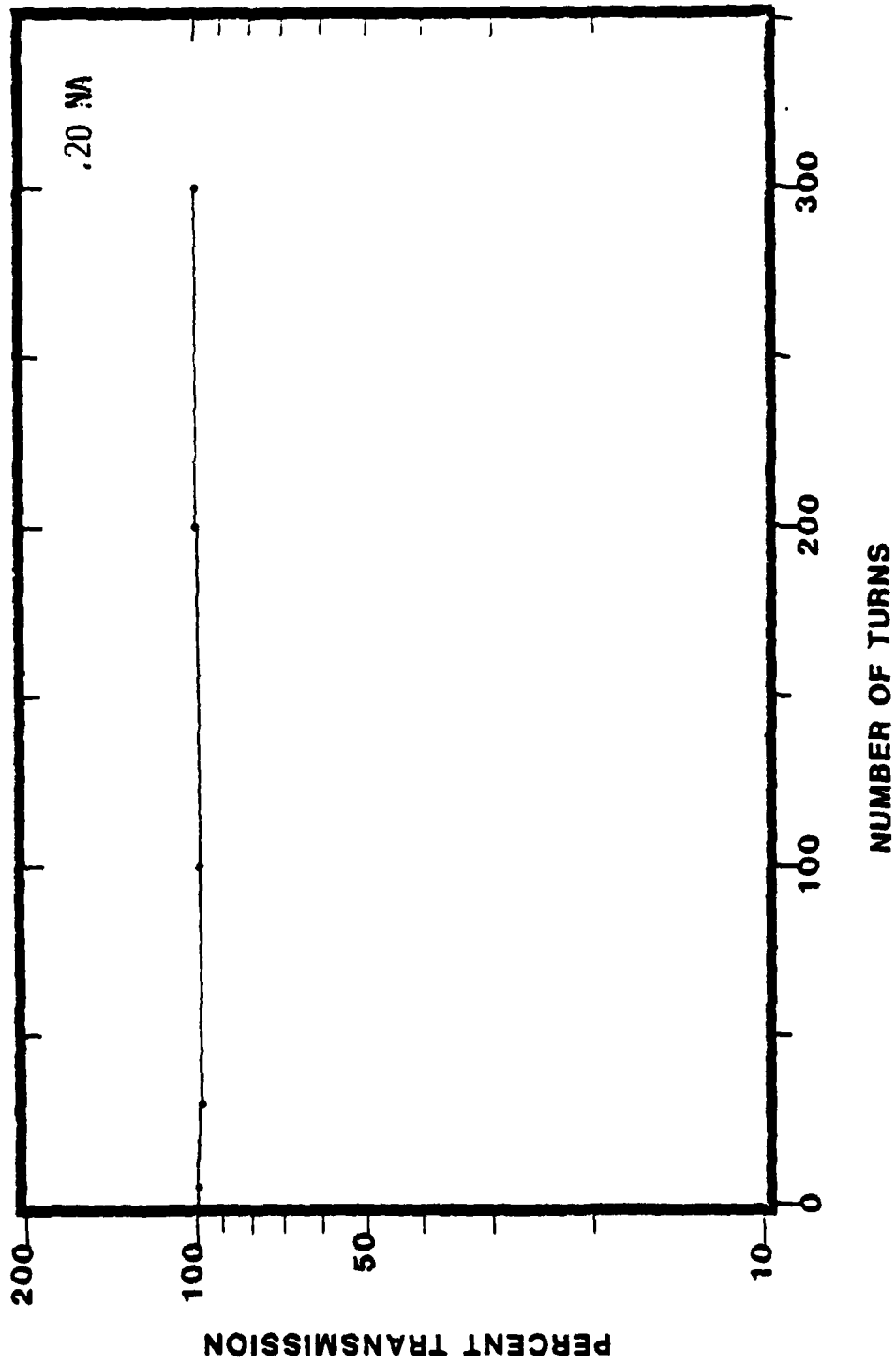
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Figure 3-14. EM-20495 - 2-cm Mandrel - 0.63282 μm .



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Figure 3-15. EM-20495 - 1-cm Mandrel - 0.84 μm .



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Figure 3-16. EM-20495 - 2-cm Mandrel - 0.84 μm .

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